Passivhaus Documentation

Single family house, Denby Dale, West Yorkshire, UK
(Passivhaus database 1779)

2.1

Bill Butcher, Project leader, Denby Dale Passivhaus, www.greenbuildingstore.co.uk

The Denby Dale Passivhaus project commenced on site in the summer of 2009, completing in March 2010 and achieving Passivhaus certification in April 2010.
The local Authority planning department stipulated that, as the house was in close vicinity of traditional stone buildings, it would need to be of the same style, using stone as the rain screen

Key features: Cavity wall construction, solar thermal panel for hot water, two storey fully glazed SW area integrated within the thermal envelope, with electrically controlled external venetian blinds for optimum solar control.

U-value external walls	0.113 W/ (m^2K)	**PHPP space heat demand**	**15 kWh/ (m^2a)**
U-value floor	0.104 W/ (m^2K)	PHPP primary energy demand	87 kWh/ (m^2a)
U-value roof	0.096 W/ (m^2K)	Pressure test n_{50}	$0.31h^{-1}$
U-value window	0.79 W/ (m^2K)	Heat Recovery	88.1 %

2.2 Brief project description

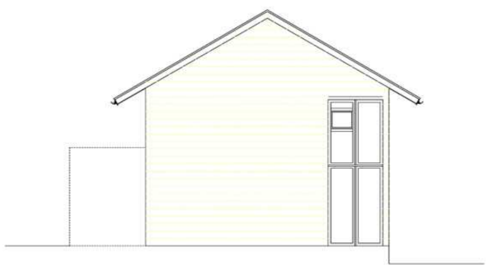
The Denby Dale Passivhaus is a 3 bed 118 m^2 detached dwelling which was conceived in the early part of 2007 for private clients who had approached Green Building Store wanting to build an energy efficient home for their retirement.

The site is located in the small town of Denby Dale, West Yorkshire. The vernacular style of West Yorkshire buildings is that of heavy masonry using locally-quarried sandstone. Therefore the construction style of the Denby Dale Passivhaus was restricted somewhat by the planning authorities. To meet these restrictions there were three construction methods available to the project team:

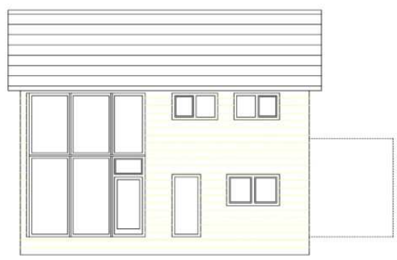
- Structural timber framing with 100mm stone rain screen walling
- Solid 225mm dense concrete blockwork, external EPS, a keying membrane and 50mm stone slips.
- Masonry cavity wall, 100mm dense concrete inner leaf, 300mm fully filled cavity with mineral wool, 100mm stone outer leaf, two leaves structurally tied together with a basalt fibre wall tie.

After considering the options we decided to opt for the cavity wall method of construction. The main reasons for this choice were the familiarity of the method for our in-house construction team, ease of sourcing and the local availability of the majority of the materials, good levels of thermal mass and cost effectiveness of the build (cavity wall was estimated to be the most economic option).

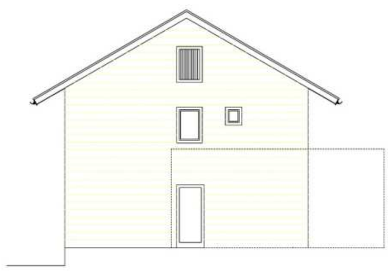
To achieve the Passivhaus standard using cavity wall construction, we needed to achieve a U-value of around 0.10 W/m²K, and adapt the construction technique for the high performance levels required by the Passivhaus Institute. We decided to full fill the cavity with a fibrous insulating material, such as mineral wool, which we decided would give us our best performance as the material would cope with the unevenness of the masonry and assists in the prevention of moisture ingress. Fully filling the cavity in this way also prevents the effect of thermal bypass, the air movement across and around the insulation. By using basalt fibre wall ties, we also managed to reduce some of the repeated thermal bridging issues associated with cavity wall construction.



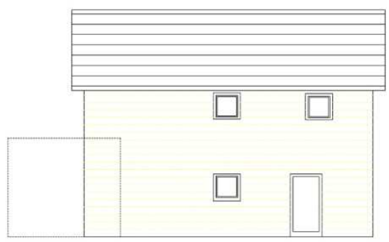
West Elevation



South Elevation



East Elevation



North Elevation

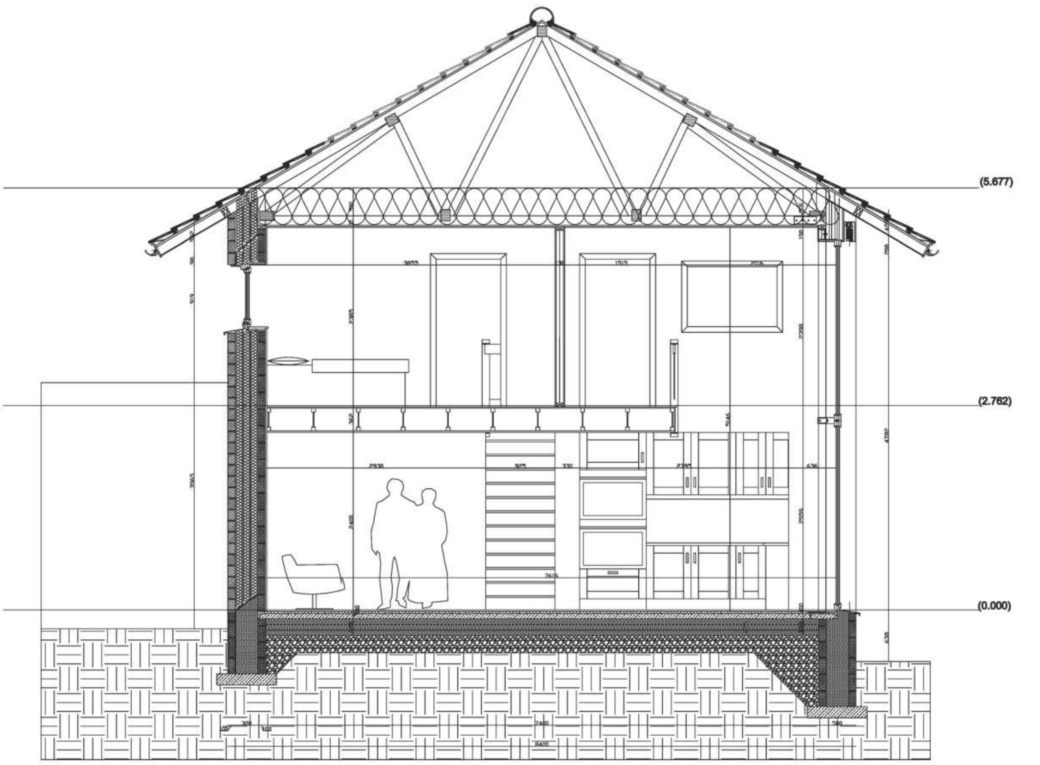
2.3 Elevations

View of all elevations of the Denby Dale Passivhaus


South and east views

2.4 Internal views


2.5 Cross section



Floor build up external to internal
225 mm Polyfoam Insulation
100 mm reinforced concrete slab
3mm underlay
14mm bamboo floorboard or ceramic floor tile

Wall build up below slab external to internal
100mm dense concrete block
300mm Plustherm EPS Insulation
100 mm lightweight insulating concrete block

Wall build up above slab external to internal
100mm natural Yorkshire stone (lime/sand mortar)
300mm fibre glass wall batts
100mm dense concrete block
13mm wet coat gypsum plaster (airtightness layer)

First floor build up
14mm bamboo floorboard or ceramic floor tile
3mm underlay
20mm T&G chipboard
302mm plywood I beam floor joist
15mm plasterboard and skim

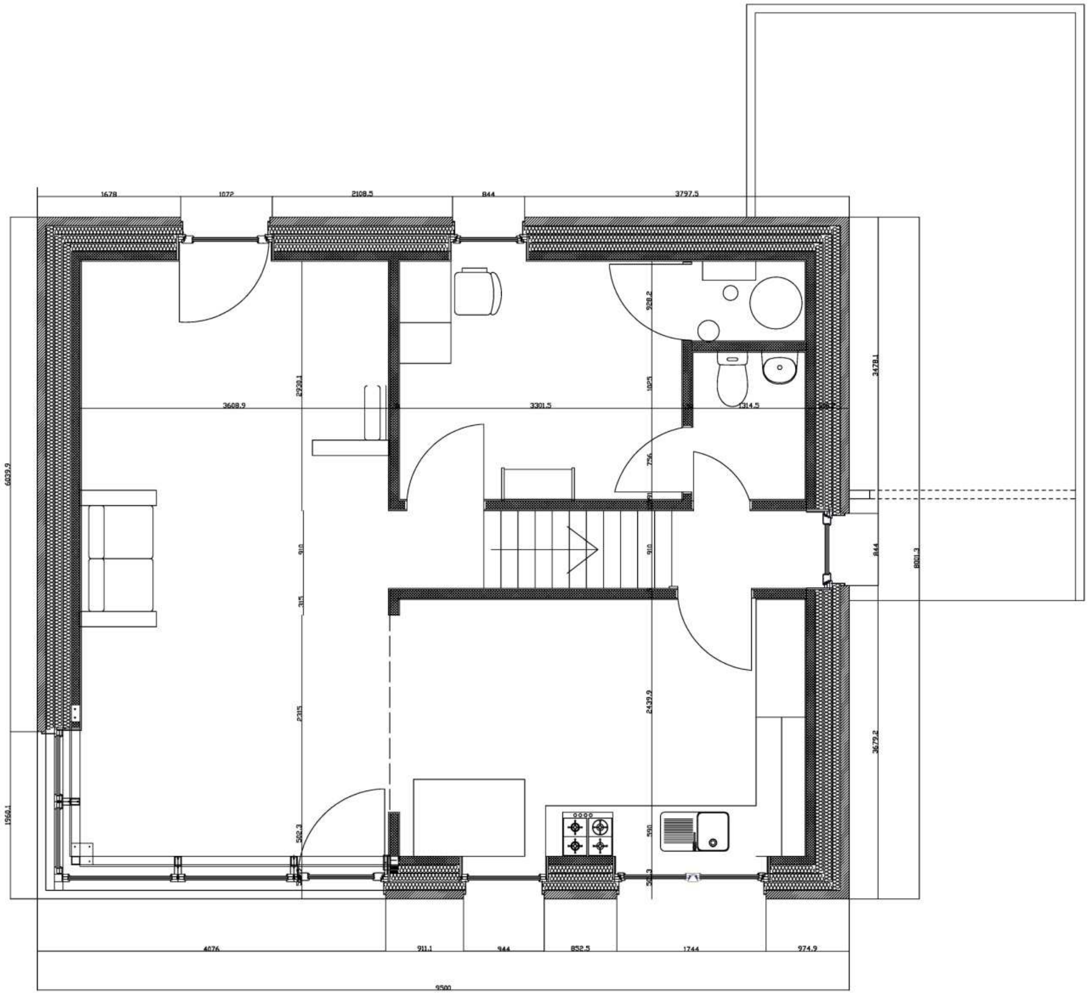
Roof build up external to internal
Concrete roofing slates
Taped breather membrane
Roof Space with 'bobtail' timber roof trusses
500mm mineral wool insulation
18mm OSB (airtigtness layer and insulation support)
15mm plasterboard and skim

External windows and doors
Triple glazed, argon filled, engineered timber windows and doors with a PU thermal break, Whole window U value 0.75 W/m2K

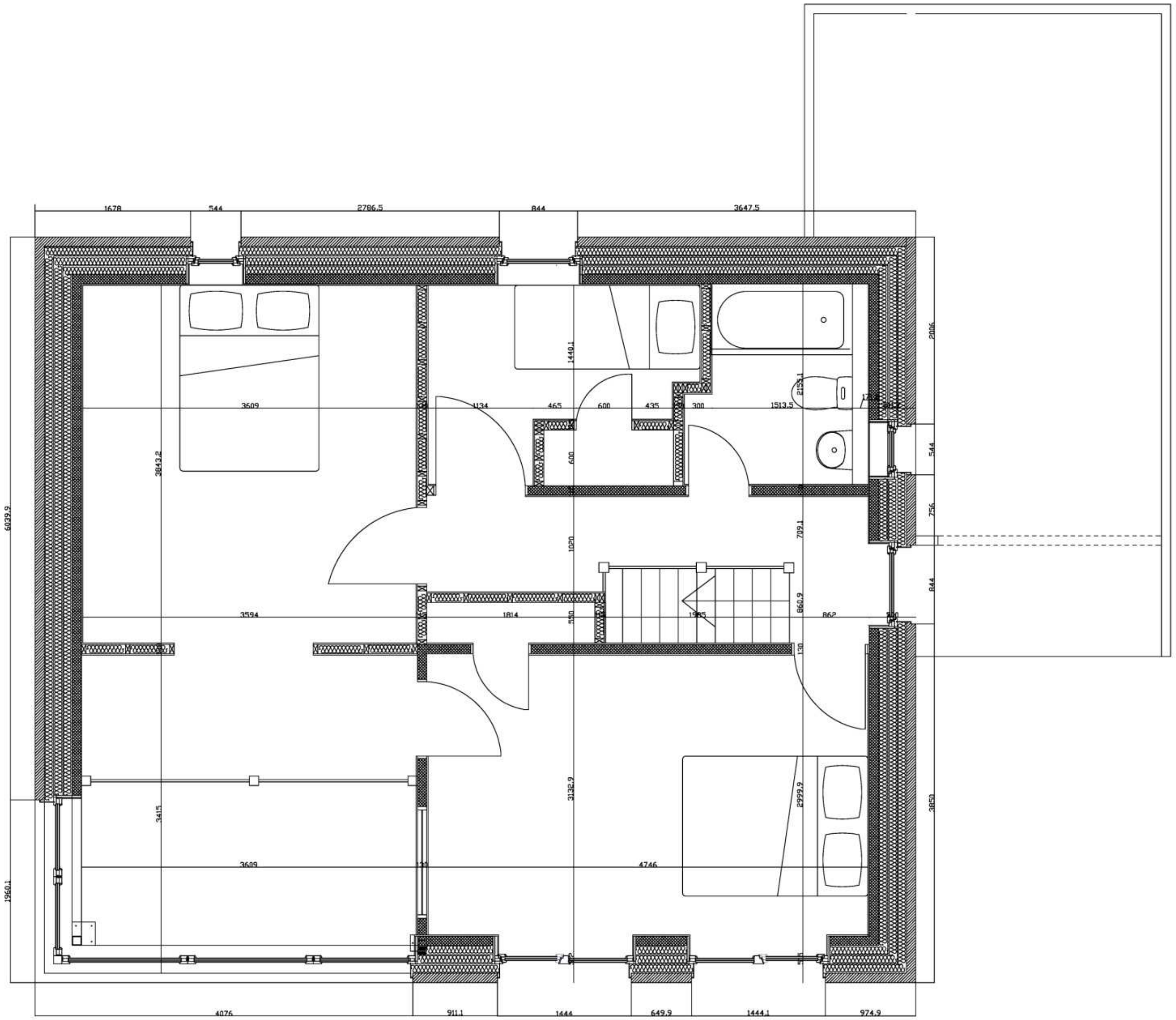
Load bearing internal wall build up
13mm wet coat gypsum plaster
100mm dense concrete block
13mm wet coat gypsum plaster

Non load bearing Internal wall build up
15mm plasterboard and skim
100mm timber stud walling insulation between studs
15mm plasterboard and skim

2.6 Floor plans
Ground floor plan

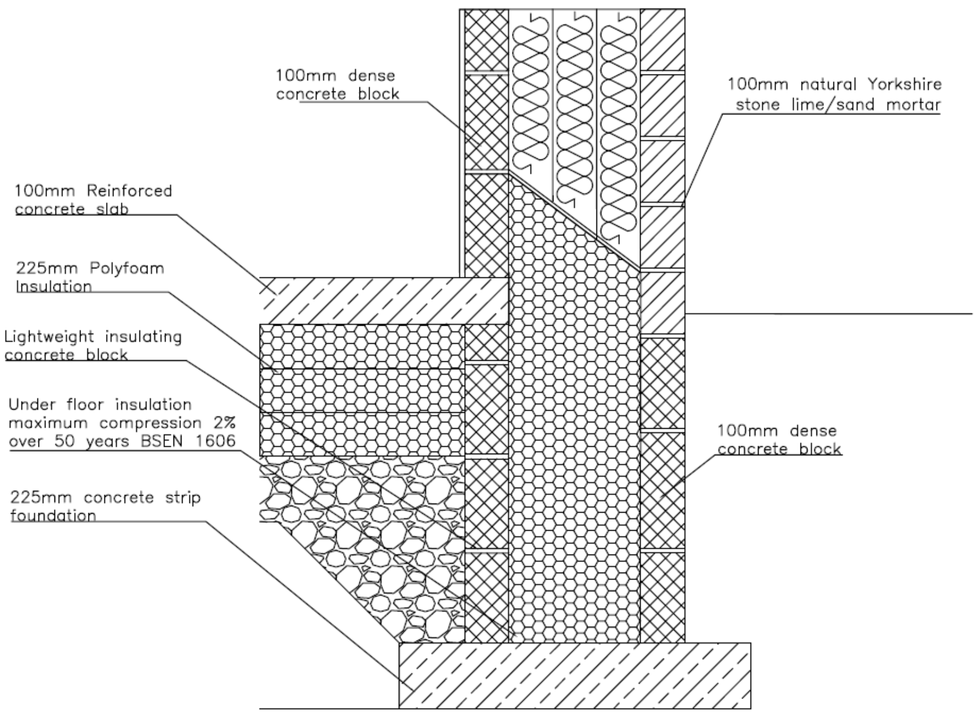


First floor plan



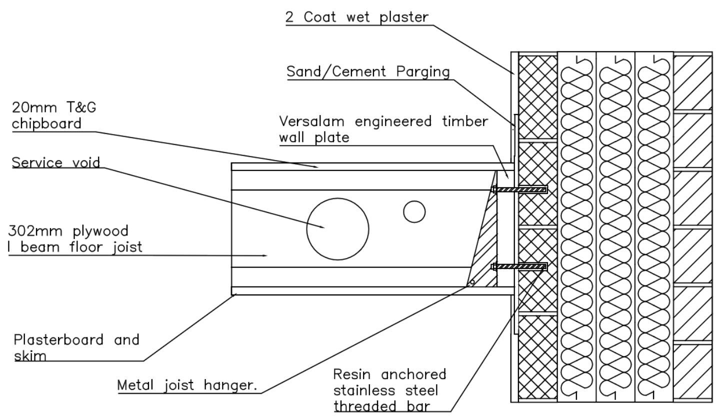
2.7 Construction details

2.7.1 Ground floor & intermediate floor details



The simple strip foundations were modified to achieve the high performance levels of Passivhaus. To help minimise the obvious thermal bridge, lightweight ‘insulating’ block was used below the floor slab and the insulation in the cavity was taken down to the concrete strip foundation level. Under floor grade EPS, with suitable compressive strength and moisture resistance, was used at this level.

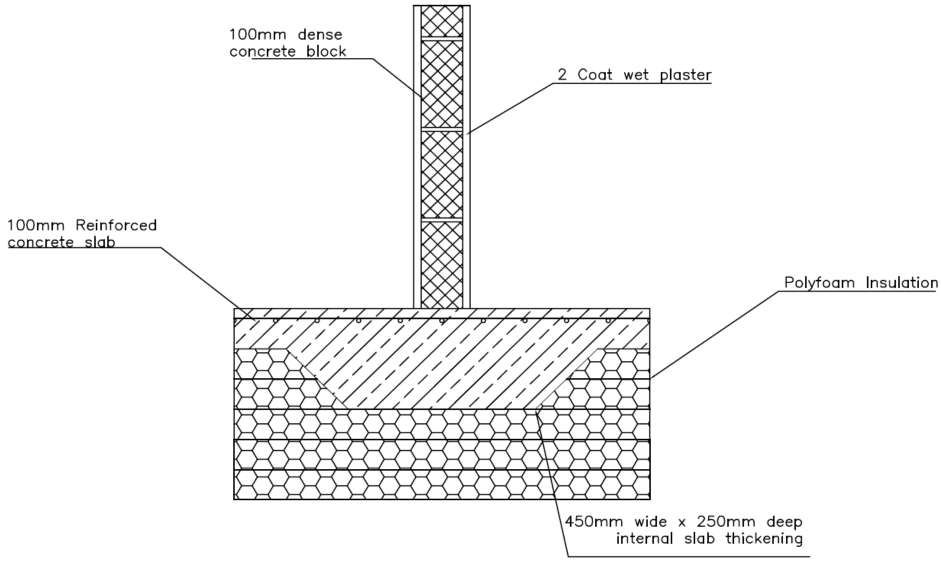
Present good practice in the UK expects a thermal break between slab and wall. However we knew this could lead to airtightness issues at the perimeter of the floor slab where it abuts the inner leaf of the external wall. We modified this detail by continuing the concrete floor slab, across the inner leaf. The internal leaf was then constructed up off the concrete floor slab. An angle was cut in the EPS and a plastic cavity tray installed to prevent hydraulic heave and water settling at this point.



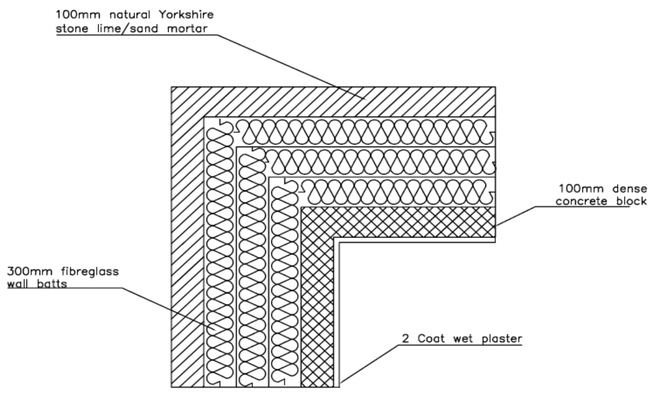
Traditionally the UK uses timber for the construction of intermediate floors in domestic properties. This method has inherent airtightness problems, even when using proprietary joist hangers into the wall this is due to the porosity of the blockwork.
At Denby Dale we decided to use 300mm deep timber I beams (TJs) we made this decision due to: cost-effectiveness, the ability to cope with large spans and the ease of running services within the void.

For airtightness at this junction, the blockwork inner leaf was rendered with a weak sand/cement coat (parging); the timber wall plates were then resin-bolted into the blockwork on top of this parged surface. Simple timber to timber metal joist hangers were used to fix the TJs. The parging was a quick and economic method to make sure the porous blockwork was air tight where mechanical fixings had to be made before the plastering process could commence. A disadvantage to this method was that the inner blockwork had to be built up beyond the floor level before the wall plate could be fitted.

2.7.2 Exterior walls & connections to other walls

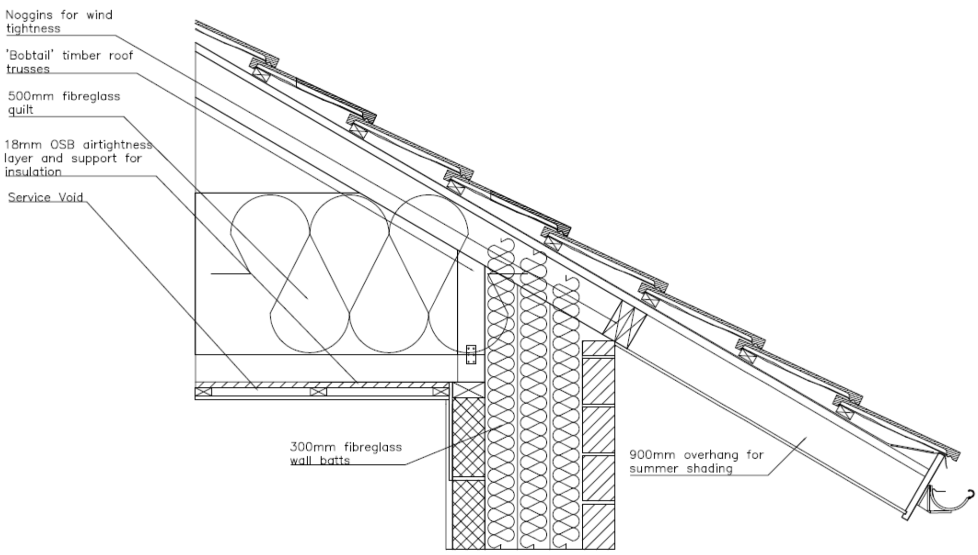


Internal load bearing blockwork wall built directly off concrete slab thickening.



Corner section through cavity wall showing continuity of insulation. Basalt wall ties were used to tie the internal and external leaves together keeping thermal bridging to a minimum.

2.7.3 Roof section

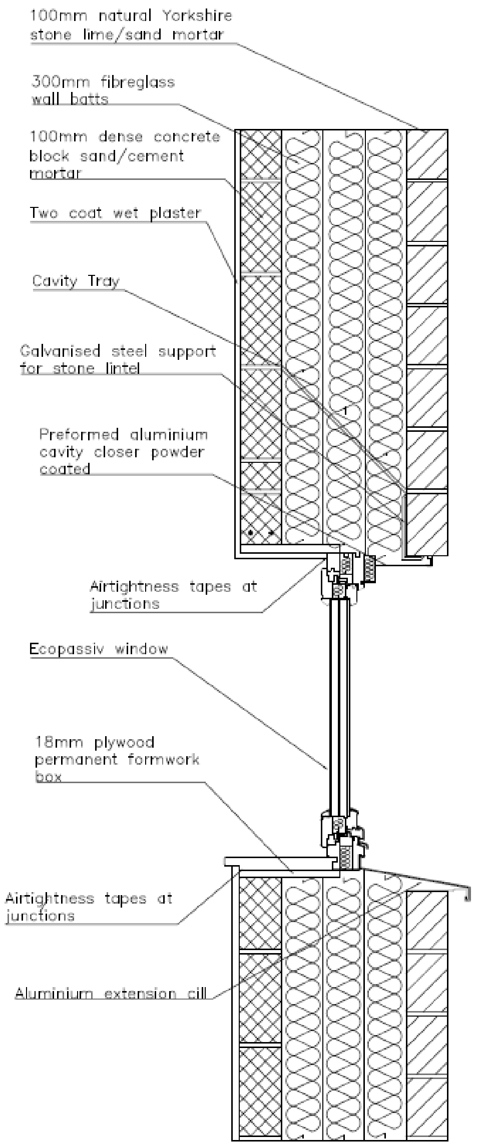


For economic reasons we used a traditional gang nail timber truss roof construction, adapted to meet Passivhaus performance. To help improve on the performance, and for no extra cost, we specified use of a 'Bob Tail' truss where a vertical member is inserted at the wall plate raising the roofline; this allowed continuity of insulation levels from the roof to the external wall eliminating the usual thermal bridge commonly present at this junction in UK buildings.

Airtightness was dealt with by the use of taped OSB boards to the undersides of the truss at ceiling level and again using specialist tapes at the perimeter into the internal wall plaster, protecting against differential movement.

2.7.4 Windows

Through the use of THERM modelling we learned that the optimum position for the windows and doors at the Denby Dale house was in the centre of the cavity insulation. Plywood lining boxes were used to form the openings in the blockwork inner leaf allowing the windows to be situated mid-way into the cavity. This approach also allowed, with the use of tapes between window frame/plywood and plywood/plaster, easy and effective airtightness.



By positioning the windows in the centre of the cavity, we then had to develop external cavity closers in the reveals. These were needed for aesthetic purposes as well as to minimise the thermal bridge through the window and door frame and close the cavity on the reveal (to give weather protection and to prevent thermal bypass). We developed our own solution to this by fabricating aluminium cavity closers, backed with PUR and powder coated to match the windows and door frames. These were let into a groove in the face of the frame and sealed against the stonework with frame mastic.

For the door thresholds we fabricated fibreglass box sections which were resin bolted to the edge of the slab and filled with PUR. This provided rigidity for fixing the aluminium threshold whilst minimising the thermal bridge.

Ecopassiv Uw = 0.75W/m²K, 100% FSC timber. Triple glazing. Polyurethane thermal break, warm edge spacers. The Ecopassiv range is supplied by Green Building Store.

2.7.5 Airtightness strategy and air test result

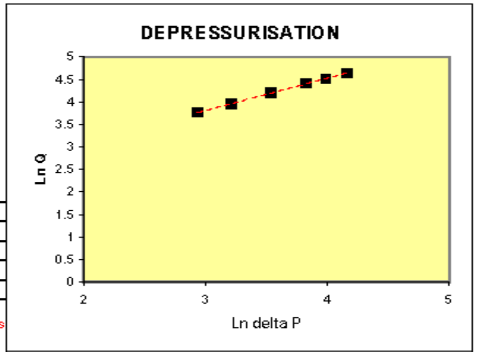
MINNEAPOLIS BLOWER DOOR DATA INPUT AND CALCULATION

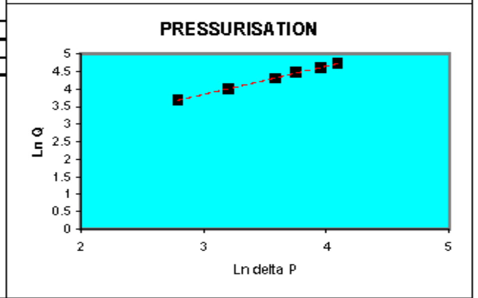
date:	11/03/2010		Version 15a 13 October 2006		
test house address:	Passivhaus, Denby Dale				
company:					
house type:	Detached				
tester:					
test reference number:			Blower Door & Gauge Used	Model 3 with DG700	
outdoor temp (℃)	6.7	℃	Note: ENSURE THAT FLOW SETTINGS ARE IN M3/HR - When using the DG700 gauge you do not need to input a baseline pressure difference as this is calculated by the gauge and the readings adjusted automatically		
indoor temp (℃)	11.5	℃			
outdoor humidity (%rh)	51.6	%rh			
indoor humidity (%rh)	61	%rh			
outdoor barometric pressure	1016	mbar or hPa	Calculated Outdoor Air Density	1.27	kg/m3
indoor barometric pressure	1016	mbar or hPa	Calculated Indoor Air Density	1.24	kg/m3
temperature corr. fact. depress.	0.983		description of main construction details:		
temperature corr. fact. press.	1.017				
wind speed (m/s):	1.8				
baseline pressure diff (Pa) (+/-)		Pa			
house width:	8.5	m			
house depth:	7	m			
house height:	5.1	m			
floor area:	119	m2			
volume:	303.45	m3			
envelope area including floor:	277.1	m2			
Pressure Difference for ELA	10	Pa			

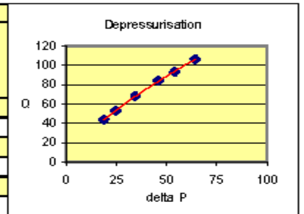
RESULTS:

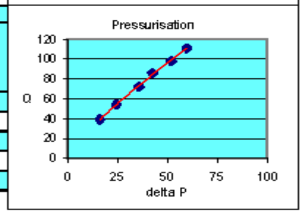
Mean Flow AT 50Pa =	93.25	m3/h		
ACH50 =	0.31	ach		
Air Permeability at 50 Pa =	0.34	m/h		
Equivalent Leakage Area =	0.003	m2 at	10	Pa

DEPRESSURISATION	RING (O=open or A,B,C,D,E)	MEASURED FAN PRESSURE (Pa)	MEASURED FLOW (m3/h)	FLOW RANGE OK FOR SELECTED RING?	Adjusted Pressure (Pa)	Ln delta P	Ln Q	Q50 Calculated Flow at 50Pa (m3/h)	Permeability Depress Only (m3/hr/m2)	ACH Depress Only (ach)
Approx 60 Pa	D	64.2	106	OK	64.2	4.162003	4.646423	88.46	0.32	0.29
Approx 50 Pa	D	54	93	OK	54	3.988984	4.515584	r2	1.000	
Approx 40 Pa	D	45.8	84	OK	45.8	3.824284	4.413801	C	0.001	m3/s
Approx 30 Pa	D	34.3	68	OUT OF RANGE	34.3	3.535145	4.202492	n	0.719	
Approx 20 Pa	E	24.8	53	OK	24.8	3.210844	3.953276	C (corrected)	0.001	m3/s
Approx 10 Pa	E	18.8	44	OK	18.8	2.933857	3.767174			
PRESSURISATION	RING (O=open or A,B,C,D,E)	MEASURED FAN PRESSURE (Pa)	MEASURED FLOW (m3/h)	FLOW RANGE OK FOR SELECTED RING?	Adjusted Pressure (Pa)	Ln P	Ln Q	Q50 Calculated Flow at 50Pa (m3/h)	Permeability Press Only (m3/hr/m2)	ACH Press Only (ach)
Approx 60 Pa	D	59.8	111	OK	59.8	4.091006	4.726546	98.04	0.35	0.32
Approx 50 Pa	D	52.1	98	OK	52.1	3.953165	4.601983	r2	0.999	
Approx 40 Pa	D	42.6	86	OK	42.6	3.751854	4.471363	C	0.001	m3/s
Approx 30 Pa	E	35.9	72	OK	35.9	3.580737	4.293682	n	0.803	
Approx 20 Pa	E	24.5	54	OK	24.5	3.198673	4.006	C (corrected)	0.001	m3/s
Approx 10 Pa	E	16.3	39	OK	16.3	2.791165	3.680577			









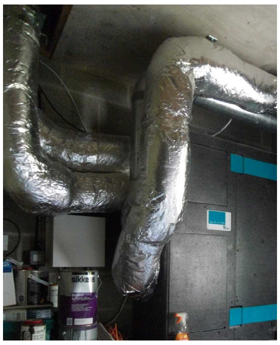
An internal two coat wet plaster system was applied to form the external wall airtightness barrier, airtightness tapes and membranes were used at the different junctions to protect the airtightness barrier from cracking due to differential movement and drying out of different materials. To our knowledge this type of system had never been used before to achieve the 0.6 ACH/hr @ 50 Pa required for Passivhaus. We developed our own designs for the floor, window and roof junction details, as these types of details were not available for the levels needed at Passivhaus. Each junction was modelled using THERM software before being entered into PHPP calculations.

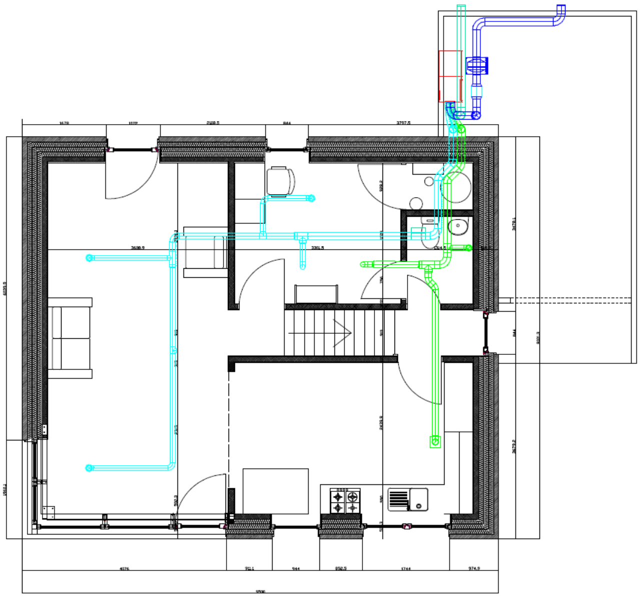
The Denby Dale house achieved an airtightness result of 0.31 ACH/hr @ 50 Pa. One major disadvantage of using cavity wall, and wet internal plaster as the airtightness barrier, is the late stage at which the test can be carried out. The building could not be tested until works such as first fix electrics, plumbing, ventilation, joinery and plastering were complete. To avoid running electrical cabling within the plaster airtightness barrier, most cabling was kept to internal walls and the floor void.

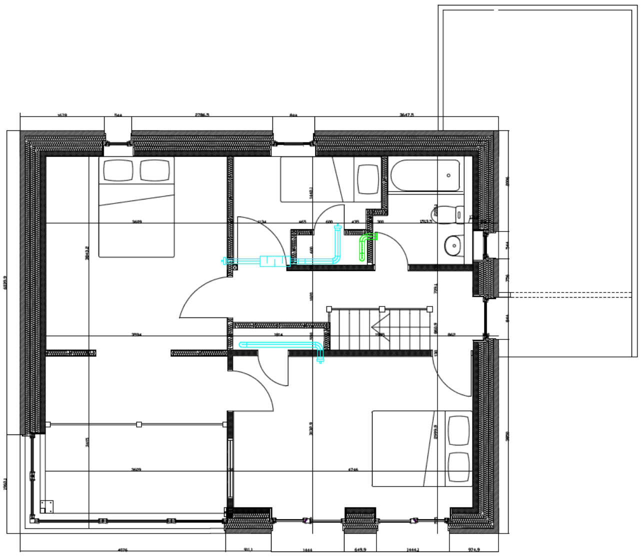
2.7.6 – 2.7.7 Ventilation strategy

For the Denby Dale Passivhaus, a Thermos 200 DC MVHR unit was installed, manufactured by the German Company PAUL and supplied by Green Building Store. The unit was housed outside the thermal envelope, in the garage due to limitations on space.

A correctly designed and installed ducting system is another essential factor for an efficient MVHR system. The MVHR ducting system has to be designed, installed and subsequently commissioned to give equal supply of air into and out of the building. If this is not so, the efficiency of the MVHR unit will be considerably effected. The installed effective heat recovery efficiency of the MVHR unit and ducting layout at the Denby Dale house achieved a total of 88.1% efficiency. It is very important that the MVHR ducting system is designed and installed correctly as it will be embedded in the fabric of the building for the life of the build. Lindab steel ducting was installed due to the robustness of the product.







Calculating the pressure drop during system design

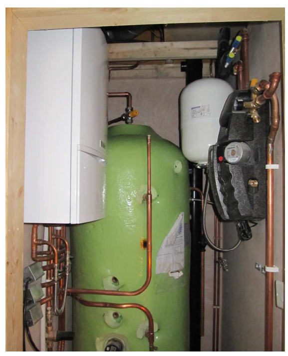
The importance of the system pressure drop is that it relates directly to the power input of the MVHR system. The lower the system pressure drop, the lower the power input required and therefore the lower the running costs of the system. While this is important, it also needs to be considered that in order to prevent some MVHR unit fans from stalling, a minimum system pressure must also be provided at a given duty in order for the fans to run with stability.

Specialist software was used to calculate the pressure drop through the MVHR system. This also checks that the system will balance without the requirement for dampers.

When commissioning, knowing the predicted pressure drop can be useful as it allows the engineer to have an educated guess at the required fan speed. If the manufacturer produces curves for power input at given duties, then it also allows for the engineer to check the power input relates to the design performance of the unit.

2.7.8 Heating strategy

Our emphasis was putting resources into the fabric of the building which are to last the lifetime of the build rather than bolt on renewable technologies. The heating method could always be altered at a later date. Having natural gas available, we decided that it was better to stay on the grid rather than going off grid for our heating needs.
The heating need for the Denby Dale Passivhaus was calculated in PHPP as being $10W/m^2$ when the outside temperature is minus 10 degrees Celsius. The Denby Dale Passivhaus has a floor area of $118m^2$ so the total heat demand was calculated at 1.18kW



The space heating at the Denby Dale house comprised of the following

- A wet duct heater installed in the supply side duct of the MVHR system to heat the ventilation supply air.
- Closed system boiler
- One radiator in the living room
- Two towel rails

2.8 Verification

Passive House Verification

Building:	Denby Dale Passive House V2
Location and Climate:	Yorkshire / GB - Manchester
Street:	
Postcode/City:	
Country:	
Building Type:	
Home Owner(s) / Client(s):	
Street:	
Postcode/City:	
Architect:	Derrie O'Sullivan Architects
Street:	28 Imperial Road
Postcode/City:	Huddersfield HD3 3AF
Mechanical System:	Green Building Store
Street:	Heath House Mill, Heath House Lane, Golcar
Postcode/City:	Huddersfield

Specific Demands with Reference to the Treated Floor Area

Treated Floor Area: 104.1 m²

	Applied:	Monthly Method		PH Certificate:	Fulfilled?
Specific Space Heat Demand:	15	kWh/(m²a)		15 kWh/(m²a)	Yes
Pressurization Test Result:	0.3	h⁻¹		0.6 h⁻¹	Yes
Specific Primary Energy Demand (DHW, Heating, Cooling, Auxiliary and Household Electricity):	87	kWh/(m²a)		120 kWh/(m²a)	Yes
Specific Primary Energy Demand (DHW, Heating and Auxiliary Electricity):	42	kWh/(m²a)			
Specific Primary Energy Demand Energy Conservation by Solar Electricity:		kWh/(m²a)			
Heating Load:	11	W/m²			
Frequency of Overheating:	2	%	over	25 °C	
Specific Useful Cooling Energy Demand:		kWh/(m²a)		15 kWh/(m²a)	
Cooling Load:	11	W/m²			

2.9 – 2.10 Construction cost:

£1525.00/m²

2.11 Year of Construction

2009-2010

2.12-15 Overviews

The Denby Dale Passivhaus was conceived 2 years ago when the clients approached the Green Building Store to construct a cost effective, energy efficient retirement home. After initial talks with the clients they decided to adopt the Passivhaus approach to the construction of the Denby Dale house.

The initial L shaped design with conservatory was dismissed straight away, after modelling with Passive house planning package (PHPP) software. A subsequent design was created, following the more classic Passivhaus shape. This new rectangular shaped building with the longest elevation facing south for optimum solar gain and integral solar space met our desired Passivhaus requirement of 15 kWh/m² /annum for space heating.

PHPP was used to look at the different options available to us with regard to insulation lambda values, thicknesses etc… window configurations, size and type. PHPP helped us to weigh up the cost implications of decisions with performance and allowed us to play off one element against another. Thermal modelling was carried out with LBNL Therm software.

MVHR services were designed, supplied and commissioned by the Green Building Store
Low energy electrics incorporating LED and florescent lighting were designed by the client and installed by Green Building Store.

2.16 Experiences

The house has now been occupied for over a year and feedback from occupants has been very positive. See occupants' blog at www.greenbuildingstore.co.uk/page--living-in-the-denby-dale-passivhaus-blog.html

Energy consumption is currently being monitored by Leeds Metropolitan University.

2.17 References

Technical briefing on the Denby Dale Passivhaus www.greenbuildingstore.co.uk/denbydalehouse

Passivhaus Diaries – our blog covering construction of the Denby Dale Passivhaus
Featured on BUILDING magazine's website www.building.co.uk/section.asp?navcode=3987

International Passivhaus Conference Innsbruck 2011 – Bill Butcher's conference paper 'Passivhaus & cavity wall construction' Working group XVI (p 551)

